Engineering and Geodetic Works during the Detailed Inspection of the Façade System of a Building Damaged as a Result of the Armed Aggression of the Russian Federation

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ABSTRACT

The paper presents the methodology and results of spatial surveying of complex façade systems as part of a detailed inspection of the technical condition of a building damaged as a result of the armed aggression of the Russian Federation. Solutions to a number of complex practical challenges are proposed, including difficult surveying conditions, intricate façade configurations, large volumes of spatial data, significant structural damage, and non-standard methods of presenting damage assessment results.

Keywords: engineering geodesy, geodetic works, façade surveying, detailed inspection, armed aggression of the Russian Federation.

1. INTRODUCTION

Today, a large number of civil infrastructure facilities are suffering significant destruction due to constant massive missile attacks by the enemy. Therefore, specialists from leading scientific and industrial institutions have developed a methodology for the inspection process, which serves as the initial data for subsequent stages of reconstruction. Engineering and geodetic support at the stages of detailed inspection plays a critically important role [1–2]. Thus, until the enemy is defeated, the relevance of such work remains fully justified.

2. OBJECTIVE OF THE STUDY

Presentation of a methodology for determining the actual spatial position of façade system structures based on engineering and geodetic measurements, aimed at supporting restoration works on the facility.

3. MAIN TASKS OF GEODETIC SURVEYING

The purpose of the geodetic survey is to determine the spatial position of the façade system structures. Since the building was exposed to a blast wave, the most severe damage occurred to the external façade systems, which served as external enclosing structures. The façade system includes windows, external finishes, and a thermal insulation layer. The main load-bearing elements of the façade system are metal guide vertical posts, horizontal crossbars, and window frames. These primary structures support the remaining façade system elements, such as ceramic cladding, windows, and the thermal insulation layer.

As a result of the blast wave impact, the main task of the engineering and geodetic survey was to identify the areas of deformation and to detect hazardous sections of the façade system structures (Figure 1).

4. GEODETIC SURVEYING METHODOLOGY

Based on the experience of performing similar works presented in [1–4], a step-by-step program for the survey was developed. The first and most important stage was the selection of appropriate surveying instruments. This was followed by site reconnaissance and the establishment of a horizontal and vertical control network. Since the inspected building is located in a dense urban area, certain difficulties arose when selecting sighting points during the control network establishment. The building is over 42 m high, and to ensure accurate surveying of the façade structures, the line of sight had to intersect the plane at an angle close to 90°. Furthermore, when using angular measurement instruments, the vertical angle should not exceed 45°, which requires positioning at a distance approximately equal to the building’s height. Due to dense urban development and the presence of damaged surrounding structures, this requirement was difficult to meet. Therefore, it was decided to establish the control network points on the rooftops of adjacent buildings, which allowed compliance with the above-mentioned surveying conditions.

Figure 1. Exterior view of the inspected structure

The horizontal and vertical geodetic control network consists of:

- sighting stations, i.e., stations from which observations of the structures were carried out. Such stations were selected to provide maximum coverage of the observed area, at an optimal distance from it, and with the requirement that the lines of sight be close to perpendicular to the observed plane;
- traverse stations, i.e., stations from which no direct observations of the structures were taken, but which form part of the geodetic polygon, participate in the coordinate adjustment

process, and serve as reference points for orienting the sighting stations;

- reference points, whose main function is to provide additional orientation for the sighting and traverse stations, ensuring reliable connection to the network.

After establishing the control points of the geodetic network, the next stage was the establishment of a tacheometric traverse, which combined angular, linear, and height measurements, enabling the determination of rectangular coordinates along three axes (x, y, z).

The traverse was carried out using a three-tripod measurement system, employing an electronic total station and two prism systems with optical plummets.

The survey of the spatial position of the structures was performed by coordinate measurement of the vertical posts of the façade system. The coordinates were obtained with an electronic total station operating in reflectorless mode. The point density during the façade system survey was selected to adequately represent the relief of the damage. The part of the façade damaged by the blast wave suffered the most severe destruction and geometric deformation; therefore, each vertical post and the vertical elements of the window frames were measured. The survey was carried out at each node of the façade system's fastening structures. The resulting spatial point cloud is shown in Figure 2.

Figure 2. Three-dimensional point cloud

5. GEODETIC SURVEYING RESULTS

To obtain the results of the spatial position of the façade structures, it was necessary to carry out office (post-processing) analysis of the geodetic measurements. The first stage was the adjustment of the closed traverse of the tacheometric survey. Next, the coordinates of the pickets (sighting points) were calculated in the required coordinate system. This produced a spatially adjusted (stitched) point cloud requiring further processing (Figure 2).

The survey results were to be presented in the form of an as-built assessment of the verticality of the façade system's posts and crossbars.

Therefore, in order to visualize the deformation zones of the façade system structures, three-dimensional surfaces of the actual vertical position of the façade were created through post-processing (Figure 3). To better understand the extent of deformations and the magnitude of deviations, the spatial surface was divided into isolines at 40 mm intervals and shaded with different colors.

For a detailed examination of the geodetic survey results, the deviations were plotted on the façade plane with "+" and "–" signs in millimeters. The "+" sign indicates deviations directed inward toward the building, while the "–" sign indicates deviations directed outward.

Figure 3 shows one of the façades that suffered the most severe damage, where deviations from verticality range from –300 mm to +300 mm.

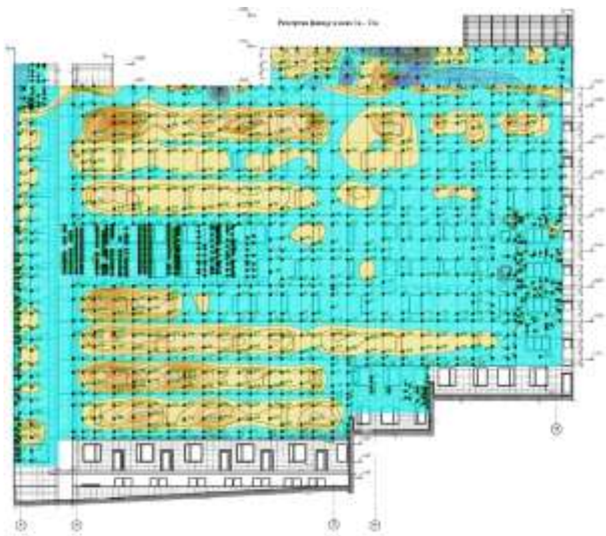

Figure 3. Deformation surface of the façade structures

6. CONCLUSIONS

Engineering and geodetic support allows for the assessment of the extent of damage and provides a quantitative characterization of the building affected by military actions.

It enables experts to focus their inspection efforts on areas that may appear undamaged at first glance.

Through the survey of the spatial position of the façade structures, it was possible to verify the integrity of the intact parts of the façade and to identify and document the damaged sections.

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